Research Paper | Biology | E-ISSN No : 2454-9916 | Volume : 7 | Issue : 8 | Aug 2021

POGIL ENHANCES UNDERSTANDING OF BIOLOGICAL CONCEPTS

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ABSTRACT

Process-oriented guided inquiry learning or POGIL is a learning model studied and shown to produce beneficial student educational and professional outcomes. This method is an active learning method that strives to encourage active student participation and focuses on career-related competencies. POGIL is a student-centered approach designed to promote group interaction and problem-solving. The role of the teacher in this active learning method is to serve as a coach and as a facilitator during student-led discussions. A condensed class lecture allows student groups to engage in conversations, leading to meaningful learning. This innovative learning tactic will not cause a financial strain on the institution and is appropriate for any science, technology, engineering, and mathematics (STEM) discipline. Initially, the POGIL approach was developed to improve chemistry courses. Since its inception, it has been implemented in other STEM courses in high school and college settings. This brief article discusses the potential advantages of using this technique to improve biology majors' understanding and application of essential skills needed in graduate school and beyond.

The incorporation of job-related skills training at the undergraduate level using POGIL can produce college graduates ready to take on the challenges of the 21st-century job market.

KEYWORDS: process-oriented, inquiry, active learning, engagement.

INTRODUCTION:

There is a fundamental link between academic success and purposeful learning strategies. Over the last 50 years, there have been dozens of learning models designed to improve several factors related to student engagement, retention, graduation, and career entry. Many of the contemporary pedagogical approaches involve the implementation of active learning activities. Essentially, active learning strategies are designed to encourage active participation and interaction during class.

All active learning strategies are considered student-centered. In student-centered classrooms, the lecture portion of a class is greatly reduced. The faculty merely serves as a guide, mentor, or coach. It is the professor's job to make sure students stay on task and answer questions if needed. During active learning strategies, professors do not answer questions directly, but rather address inquires in a general or indirect way to allow students to deduce accurate knowledge. The purpose of this article is to examine an active learning technique known as the process-oriented guided inquiry learning (POGIL) pedagogical system.

POGIL was initially established to enhance chemistry-based courses by Moog and others (Moog, Creegan, Hanson, Spencer, & Straumanis, 2006). Since then, it has been used in several other math and science disciplines (Mulligan, 2014; Roller & Zori, 2017; Soltis, Verlinden, Kruger, Carroll, & Trumbo, 2015) and have even been used for large online classes (Reynders & Ruder, 2020). The POGIL system is deeply rooted in constructivism, an epistemological conceptual framework that places the burden of knowledge construction on the individual student (Rodriguez, Hunter, Scharlott, & Becker, 2020). Progenitors of the constructivists model believe that once students are placed in the appropriate academic environment and subjected to student-centered activities, they should have the capacity to construct or build an accurate understanding of discipline-specific content and apply that content to real-world situations.

POGIL:

In a traditional lecture-formatted class, the professor is the dominant figure in the information transmission process. In this type of class, the lecturer talks 75%-95% of the time. Alternatively, in a POGIL-formatted class, the professor is not in class to answer questions directly; instead, the professor is there to ask leading or guiding questions that allow the student groups to construct the answers and insight on their own. The constant use of group work enhances team-building skills essential in the modern workplace (Myers, Monypenny, & Trevathan, 2012). As its name implies, the POGIL method allows students to explore a topic and build understanding by addressing increasingly complex questions designed to target higher-order thinking skills (Figure 1).

Application of the flipped pedagogical paradigm can be used to modify the POGIL method for maximal effectiveness. Before the POGIL experience, submitting pertinent online biology content videos 1-2 days before the POGIL activity may lead to more significant gains in learning and comprehension of biological concepts. Coupling the viewing of online content videos with brief, focused online quiz assignments will allow biology faculty to assess whether students have a solid understanding of foundational material. Evaluation of a predetermined comprehension benchmark percentage will dictate the utilization of and the focus and duration of additional review of biological topics in-class before the guided inquiry segment of the POGIL. In terms of classroom architecture, using the student-centered active learning environment for undergraduate programs (SCALE-UP) architectural designs could also facilitate POGIL instruction. SCALE-UP classrooms are marked by separate learning units consisting of evenly spaced tables in the room containing chairs for a specific number of students (Felege & Ralph, 2019). The separation of students into groups allows the instructor to assist and monitor each group. Virtual reality (VR) or augmented reality (AR) headsets can facilitate remote interactions and extend the nature and authenticity of the issue under investigation (Pellas, Dengel, & Christopoulos, 2020; Shu & Huang, 2021). Figure 1 illustrates a microbiology-based POGIL activity that can be employed in an undergraduate class. Question development adopts Bloom's taxonomy in terms of degree and difficulty (Krathwohl, 2002). Initial questions target lower-ordered thinking skills, while later activity questions target higher-order thinking skills.

POGIL Evidence:

The POGIL research landscape is expanding incrementally as more STEM professors are becoming aware of the potentially transformative nature of this dynamic learning tactic. Traditional POGIL-related research has focused on how POGIL affects grades, problem-solving, science process skills, scientific communication, team-building skills, and other cognitive skills (Hein, 2012; Irwanto, Anip, Rohaeti, & Prodjosantoso, 2018; Toyo, Aji, & Sundaygara, 2019; Vincent-Ruz, Meyer, Roe, & Schunn, 2020). However, more POGIL efficacy data is needed to validate the pedagogical procedure. Moreover, efficacy data regarding educational outcomes (e.g., retention), broadening participation factors, and other psychosocial benefits to minority groups such as African Americans, Hispanics, Native Americans, and Pacific Islanders are nonexistent. Data distinguishing the effects on POGIL in two-year, four-year, public, and private institutions should also be explored. It would also be interesting to observe any gender differences in terms of educational or professional benefits of using the POGIL method. The number of literary resources on the use of POGIL and biology courses is minimal. A search using the educational resources information center (ERIC) and PubMed databases yielded a small number of relevant resources. POGIL-based biology resources are shown in Table 1.

CONCLUSION:

The implementation of high-quality learning strategies designed to prepare college students for the future is in high demand. In summary, POGIL is an active learning pedagogical tactic that employs guided questions facilitated by the instructor to enable student knowledge and process skills. The collaborative nature of this approach is a critical factor that exploits the social nature of most college students.

POGIL has been used to focus on biological content and complementary skills such as designing scientific communication projects or comprehending primary research literature. From a STEM education research perspective, this technique has a seemingly unlimited number of research investigations that can be explored to show this didactic methodology's relevance further. Since this approach has relevance in virtually every field, especially STEM fields, more research should be done to validate efficacy. At this stage in this technique's life cycle, there must be validation of POGIL in biological disciplines from anatomy to zoology. A variety of mixed methods can be performed to study the efficacy of the POGIL modality. Most of the work found in education literature databases focuses on how the technology improves performance on exams and course grades. A technique that improves students' grades is highly beneficial; however, POGIL also purports to enhance other necessary academic and workforce proficiencies such as scientific communication skills, managerial skills, team-building skills, critical thinking skills, and a host of other skills needed in the professional world. Examining the effect of POGIL on the above skills using valid and reliable surveys is a necessary step. Additionally, constructs such as self-efficacy, motivation, scientific reasoning, engagement, satisfaction, vocational purpose, career commitment, and career interests must also be evaluated to determine how the strategy impacts other areas that benefit student development. A recent study by Blumer and Beck (2019) suggests that utilization of inquiry-guided approaches can improve scientific reasoning for students who lack adequate background subject knowledge. Scientific reasoning is a type of reasoning that utilizes inquiry to analyze and evaluate scientific concepts, experiments, ethics, and data. Determining the efficacy of POGIL to target highly elusive dependent variables, such as scientific reasoning in college is paramount for the sustainability and utility of this technique as a teaching, training, and mentoring tool.

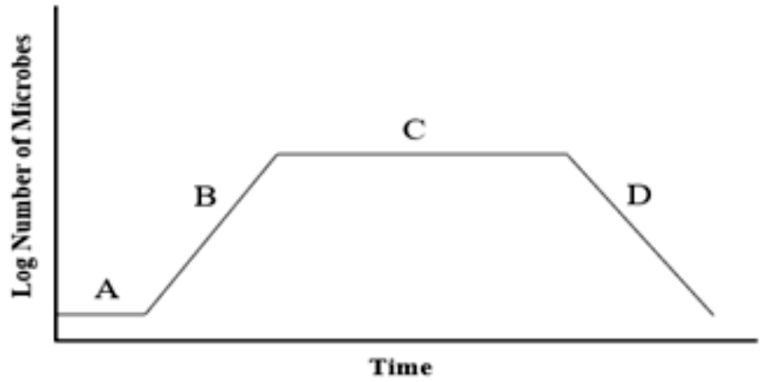
ACKNOWLEDGMENTS:
This work was supported by a grant funded by the National Science Foundation (HRD-1533536).

Analysis of Bacterial Growth Curves

Inquiry Overview
What are the factors that affect the growth of bacteria?

Foundational Content:
Prokaryotic microbes possess a characteristic propagation rate that can be visualized by plotting cellular growth over time. Bacterial growth curves provide a graphical representation of the growth phases of a microbial population within a specified period. These curves illustrate bacterial biomass expansion quickly and contraction stages and help microbiologists classify microorganisms and determine the requisite elements (e.g., growth factors, temperature, pH, etc.) for optimal growth for a specific bacterium. There are four major stages of bacterial growth: lag phase, log phase, stationary phase, and death phase (Model 1). The lag phase is marked by a lack of bacterial growth but intense metabolic activity (A). The log phase is a period of exponential cellular increase (B). In the log phase, microbial growth is represented by an upward slope in the bacterial growth curve. The stationary phase is when the number of cells that are multiplying is equal to the number of cells that are expiring (C). The death phase, represented by a downward slope, suggests that factors that support bacterial growth have greatly diminished, and the cellular population is decreasing rapidly (D). Student groups will explore evidence-based predictions regarding the nature of bacterial growth based on environmental conditions.

Model 1 - Bacterial Growth Curve



POGIL Activity Questions

1. What are bacterial growth curves? What are the four phases illustrated in a bacterial growth curve?
2. Which bacterial growth curve phase illustrates the period of exponential bacterial proliferation?
3. Describe the growth conditions in the culture flask during the stationary phase.
4. Sketch a bacterial growth curve in which toxic compounds in media where efficiently removed over time.
5. Compare and contrast underlying bacterial processes during the lag and log phases.
6. Which area of the bacterial growth curve shows the growth of an obligate aerobe in which oxygen is presence?
7. Which area of the growth curve shows the growth of a bacterium recently placed in a new growth medium?
8. Which area of the bacterial growth curve shows the growth of a halophile in the presence of 10% NaCl?
9. Discuss how pH of the growth medium affects bacterial growth.
10. Which area of the bacterial growth curve shows the growth of a hyperthermophile cultured at 37°C?
11. Which area of the bacterial growth curve shows the growth of a psychrotroph cultured at 4°C?
12. What are the drawbacks in using spectrophotometric analysis to evaluate microbial growth?
13. Devise an experiment to determine the growth rate of a psychrophile, anaerobe, and mesophile.

Figure 1. Microbiology POGIL activity.

Table 1. POGIL Biology Literature

Subject	POGIL Outcome	Reference
Anatomy & Physiology	Student performance/satisfaction	Brown (2010)
Biochemistry	Knowledge gains/critical thinking	Minderhout & Loertscher (2007)
Biochemistry	Knowledge gains in a large class	Bailey, Minderhout, & Loertscher (2012)
Primary Literature	Understanding of research articles	Murray (2014)
Scientific Posters	Scientific application skills	Brown (2020)

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